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ABSTRACT

The application of behavioral and cognitive learning theories to the design of computer-assisted instruction (CAI) at the college level is discussed. A model of instructional design and the unique qualities of computers are also briefly reviewed. The general model of instruction, which is used for designing a curriculum, has five major components: objectives, pre-assessment, instruction, evaluation, and feedback. When planning CAI it is necessary to determine what outcome should occur from instruction. Once objectives and items for pre-assessment have been determined, method of presentation must be determined. CAI is broken down into four major types of presentations: drill and practice, tutorial, simulation, and problem solving. The method of design includes content development, presentation development, frame design, response assessment, feedback/reinforcement development, and post-assessment. Content development concerns the selection and "story line" of the information presented in the CAI, while presentation development involves the design of strategy for presenting the content effectively. The contributions of various learning theorists to the various phases of CAI design are considered, with attention to theories of Hull and Thorndike, Skinner, Pavlov, Guthrie, Piaget, Estes, Bandura, and Gestalt theory. (SW)

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A Personal Application of Learning Theory to the Design of Computer Assisted Instruction for Higher Education

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Introduction

Somewhere in the catacombs of time a simple question has been lost. A question which could easily explain why the complicated, and sometimes what seems incipherable, information we call learning theories are in existance today. The question? How does a person learn? The final results aren't in yet, so we have to take the bits and pieces we think we understand and apply them the best way we know how.

The purpose of this paper is to do just that. Take major learning theories and attempt to suggest ways they may be used to assist in the design of computer assisted instructional software, the end goal being increased effectiveness, simplicity of design and educationally sound computer instruction, based on major learning theories.

Learning theory is the backbone of curricular and media design. Without learning theory we have no assumptions to guide us in making curricular and media planning decisions. We are left at the mercy of individual constructs which are not broad enough to allow curricular planning from beginning to end. For example the media specialist would probably concentrate on the visual/auditory design of instruction, using the various "tricks" and "secrets" of media design to send a message, with emphasis on sending the message, as opposed to determining it. The teacher, on the other hand, would place emphasis on determining the importance of the message itself and how to incorporate the various existing media materials within instruction to cause learning to take place.

Learning theory is also important in allowing curriculum specialists to predict expected outcomes of various instructional strategies, there by providing a tool for pre-planning without having to constantly depend on trial and error and post-planning to develop meaningful and effective instruction.

In this paper, after breifly discussing a model for instructional design and the unique qualities of computers, I will attempt to explain how major learning theories, or parts thereof, may be applied to the design of computer assisted instruction.

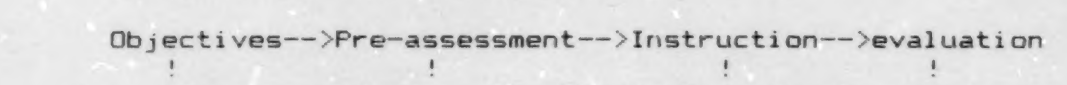
The process of design

In order to fully understand the application of learning theories to computer software design, it is important to know about the process of software design, i.e. what procedures are used to begin the design. The process begins with a model of instruction. A matrix for curricular design. There are many models for designing instruction, each with

their own unique set of characteristics. However the model which is considered most universal in its application is the General Model of Instruction.

The General Model of Instruction

The general model of instruction is a model for designing curriculum, and because of its flexibility may be used as a guide to design the teacher's daily lesson plan, or a state or national curricular program. There are five major components of the model. These are, objectives, pre-assessment, instruction, evaluation and feedback, as shown on the schematic below.



Objectives

The general model of instruction assumes the existance of predetermined objectives, i.e. the curricular designer has already determined what the "content" for the project at hand will be.

Pre-assessment

Pre-assessment involves the evaluation of the student to determine if he has already attained the various objectives, as well as to determine if the student is capable of accomplishing them. Those objectives the student has attained are then dropped from the program and those which may be too difficult, for any number of reasons, are either altered, or substituted with other attainable objectives (feedback).

Various techniques are used to evaluate the student for objective attainment. If the objective is written in behavioral form then the measure for attainment will be stated in the objective itself. If not stated in behavioral form, formal measures, such as tests, or informal measures, such as teacher observation may be used to determine attainment.

Instruction

After the objectives have been determined, and the student has been evaluated to determine objective attainment, instructional methods and audio-visual materials are matched with the various objectives. Various criteria, from availability of materials, to particular student needs are used to determine the appropriate method for each objective.

Evaluation

After completion of the instruction students are evaluated to determine if they have attained the various objectives, and the instruction is evaluated to determine how successful it has been. If results of the instruction are poor then after determining the possible cause, changes are made in preparation for the next cycle (feedback).

Feedback

At all points along the model evaluation is taking place so as to provide feedback for the various planning phases. This assists in improving the effectiveness of the instruction, whether it be changing the objectives, or altering the instruction.

Typically the GMI is applied in the manner which has just been described for traditional instruction. As we shall see the model is very useful, when combined with major learning theories, for specifically designing computer assisted instruction (CAI).

Computers and Learning

The use of computers in education is so new educators are still guessing at its affects on learning, as well as what the best method for using them are. however, they have identified several positive attributes computers possess which makes their use beneficial in teaching. If you will notice "computereese" is chock full of learning theory terminology, and as we will see later, generally the terms have similar meaning. These include, just to mention a few, the ability to: give instant FEEDBACK; provide numerous methods of REWARDING students for correct RESPONSES; continuously evaluate student's RESPONSES and progress; repeat instruction infinately, without making "prejudiced responses" and; MOTIVATING students to learn.
The exchange between computer and student can generally be described as the schematic below shows.

Stimulus->Response->evaluation->feedback->stimulus->response

The Appplication of Learning Theory to Computer Software Design

The application of learning theory to the design of computer assisted instruction is complicated because of the murrid applications of the theories at each juncture of planning. But with an organized and systematic approach a deep understanding and appreciation of their application can be seen. To attempt to apply pure research to the instructional phase of learning is next to impossible. As

Hilgard and Bower in their text entitled Theories of Learning , (1975) suggest "... the heavy reliance on sheer empiricism to supplimert derivations from theory suggest the need for an explicit theory of instruction which takes these empiracal steps into account."

Let's begin by summarizing contributions the various learning theorists have contributed to the various phases of CAI design.

Objective and Pre-assessment Development

When planning CAI it is necessary to determine what outcome you would like to have occur from the instruction. You ask yourself, "what behavior do I want the student to have following instruction (reponse, though not in the terms of muscle movement or glandular secreation, but in terms of cognitive change as well)?" followed by "How do I get this behavior (What stimulus?)?" This requires the identification of an objective. Thorndike would suggest we keep the law of readiness in mind when planning the objectives and pre-assessment. Trying to teach a student something he is not capable, or ready to learn is annoying and may negatively affect the outcome of the planned instruction. Hull and Thorndike would also suggest events must occur before instruction to prepare the student to learn or perhaps, even the student should play a part in selecting the goals (Organism directed learning, Thordike and Drive condition or motivation suggested by Hull).

The computer allows the designer to incorporate "active assessment determiners" within the software so as to customize instruction for EACH INDIVIDUAL using the CAI, i.e., each student's instruction is designed, by the computer, based on pre-assessment of each individual student at the time the student is using the CAI.

This suggests we ask ourselves the following questions, based on learning theory, when determining objectives and planning pre-assessment for instruction:

1. What behavior (response) do I want from the students following instruction?

    1. Are the students ready for (or capable of accomplishing) this objective? (Law of readiness)
    2. Is it possible to stimulate the students interest in the objective's content?

Once objectives and items for pre-assessmen. have been determined, method of instruction, or, in the case of CAI, method of presentation must be determined.

Method of Instruction

Computer Assisted Instruction is broken down into four major types of presentations. These are, drill and practice,

tutorial, simulation and problem solving.

Drill and practice is Computer Assisted Instruction (CAI) based on reinforcement of previously learned material. A typical drill and practice CAI might present a multiplication problem and ask the student to type in the answer. The computer would then evaluate the student's response and provide positive or negative feedback to the student, based on the correctness of the student's answer.

Tutorial programs present new information to the student, i.e., information the student has not been exposed to before. Information is presented in a motivating way and the student is periodically asked to respond to information displayed on the screen so the computer may evaluate the student's progress. It is typically considered the most ineffective of all the CAI methods of presentation.

Simulation software, is CAI which models real life situations and places students, based on the student's response, in situations in which the student must make choices to escape various problems. It is designed specifically for teaching interrelationships. A good example would be a simulation used to teach airplane pilots how to fly.

Problem solving CAI is similar to simulations with one exception, the student must come up with the solution, relationships might be present, but the student is left with the task of identifying options and relationships, as opposed to selecting from a list of options.

Though each of these methods have characteristics which are unique when compared to each other, the method of design is similar. The phases include development of; content; presentation; frame design; response assessment; feedback/reinforcement and;post assessment.

Content Development

Content development concerns the selection and "story line" of the information presented in the CAI. It involves organizing and writting the information to be included in the instruction. It is written as if a it were a paper which is being presented to students and should not be a script. Based on Thorndike's S->R theory, the material presented should be written so as to reduce conflict and frustration, or at least written in such a way as to allow students to resolve and accommodate conflict. For example students should be allowed to respond immediately after veiwing cue. Not to be able to respond when ready is annoying. Content should also keep in mind retention is based upon learning with understanding, so the material should be presented in such a way as to be logical, or as Skinner would say, in a programmed manner.

It is also important at this phase to evaluate the material to determine if some of the material should not be presented together, so as to follow the "law" of belongingness, i.e. we remember some material because it seems to belong together (Thorndike).

This suggest we ask ourselves the following questions when designing the content.

II. What method of instruction do I want to use?

A. Content
1. What is the content of the instruction?
2. Is the content presented in a pleasing way which will reduce conflict and frustration?
3. Has the content been organized and written in such a way the student will learn with understanding and retention?
4. Is all specific information which is related presented in such a way as to retain the relatedness?

Presentation Development

Presentation development refers determining how you plan to present the content. It involves the designing of strategy for presenting the content in the most effective way. This is where the attributes of the various types of CAI come into play. For example, if you are trying to reinforce information already learned you would select drill and practice CAI. This would suggest the use of Skinner's operant conditioning and shaping since the purpose of this type of CAI is to reinforce information or skills already learned. Even Thorndike's principle of spread of effect and the recency principle of Guthrie should be used in determining the development of presentation.

Typically presentation follows a pattern determined by the pre-assessment, and is a branching design, so students will not have to spend time relearning or reinforcing information or skills which they have already mastered (Thorndike's law of readiness), but can spend their time on information and skills which need further development. It is determined by marking a box, in pencil around each bit of information to be presented in a particular frame on the final content paper. In the next phase of development, frame design, this information is arranged for most effective communication.

It is also at this time positive reinforcement is planned. I.e. the development of strategies for encouraging student attentiveness and rewards for responding correctly to instructional questions. In my opinion one of the most useful of all learning theories is the idea of positive feedback. Depending on the age and need of the student population for which the CAI is designed, a song may be played while a visual is presented on the screen, or a paper certificate or award may be printed with the student's name on it to reinforce a correct response and encourage continued success for the student (Skinners positive reinforcers). CAI seldom uses negative reinforcement, though

it does sometimes use extinction.

Based on the above discussion of pertinent learning theory, the following questions should be asked in this phase of development.

B. Presentation
   1. Are you breaking the content into digestable frames?
   2. Is the content divided in a way to produce the expected end behavior?
   3. Do you have a reward which is motivating and will encourage the student to be attentive to the CAI content?
   4. Is your strategy appropriate for the content?

Frame Design

Once you have determined the contgnt presentation it is necessary to design the "layout" of the screen. I.e., determine how you are going to present each frame of content. Options include graphics (drawings) or text. The theory of response by anology, as suggested by Thorndike and Pavlov's generalization play an important role in this phase of development. When designing CAI the designer must always take into account the student will make a mistake in HOW he responds to a stimulus from the computer. This suggest the screen be laid out in such a way as to be similar to previous screens so once students learn how to respond or where to look on the screen for new information or instruction for one frame, it will not be necessary for them to look elsewhere on the screen the next frame. For example perhaps instructions ALWAYS appear at the top of the screen in every frame, instead of one frame having instruction at the bottom of the sreen, another at the side and so on. This allows the student to concentrate on learning and assists in helping the student feel in control of his learning.

Cueing is also important in this phase of design since the student must know when and how to change the frame when he is ready to move on. Therefore the designer should develop a cue to inform the student when to continue. A bell sounding, a word flashing or any number of other cues could be used.

Frame design is determined by taking each of the boses marked earlier in pencil on the content page, and drawing a picture of what is to appear on the computer sreen for that particular information frame. The basic design principles used in graphic arts, in cooperation with screen continuity, determined earlier, are used to determine layout of each frame

C. Frame Design
   1. Are the screens lay outs similar?
   2. Have you provided cues for the student so he will know when to respond to the frame?

3. Are your method of frame presentations appropriate for each frame?

4. Do the frames collectively fit the flow strtegy of the CAI?

Feedback Development

Once the strategy has been determined and the frames to communicate the content designed, it becomes necessary to develop the feedback "loop." When the computer asks the student to respond to a question and the student responds, it is important the student receives immediate feedback in the form of positive reinforcers, if correct response or in the form of seeing the right answer if the student repsonded incorrectly.

Several learning theorists suggest the importance of reinforcement, some such as Guthrie, to simply mark the end of a situation to Skinner's operant conditioning, and Hull's drive theory. Important also is the time between the reinforcer and the correct response. Pavlov suggest the reinforcer be kept consistant in terms of it's makeup so extinction will not take place. Therefor when designing positive reinforcers it is necessary to keep the variance of the reinforcer very limited so each time it is used it will be identifiable by the student.

D. Feedback/Reinforcement

1. Is the reinforcement likely to be appropriate and effective for the student population?

2. How consistant is the feedback?

3. Is the feedback immediate?

4. Is there continuity with variance in the reinforcer?

5. Does the reinforcement interfere with the learning task?

Post Assesssment Development

Following the design of the actual instruction itself, it becomes necessary to evaluate the student's progress through the CAI. This is accomplished through post-assessment and involves basically the same procedure as other instructional methods. It allows the student to receive reinforcement for retention of the learned content.

The Application of Cognitive Learning Theory to Computer Software Design

The previous section emphasized the application of behavioral learning theories to software design. This section will emphasize the application of cognitive learning theories. As I have outlined and summarized the information concerning the various theorist and theories for this section I find the real difference between the application of the models will not appear to be present. The real difference will reside in the rationale for the presence of various attributes.

One of the most important aspects the cognitivists bring to software design is the methodology to observe behavior, both in quality and quantity. Estes's Mathematical Learning Theory has direct application to the research of human reaction to the machine called the computer.

Recently I read an article which summarized observations concerning the maximum number of students to assign to a microcomputer to insure the social learning many say computers destroy. Social theories can play an important aspect in this area of software design.

The Gestalt principle concerning continuity should be applied accross all phases of software design. If the content or screen design is presented in a haphazard, unorganized way, then the chances of the student learning the content will be less.

Objective and Preassessment Development

As mentioned earlier it is necessary to determine what the purpose or objective is to be before the actual synthesizing of the CAI. Piaget would suggest as we begin to develop the objectives we keep in mind the mental and physical abilities of the student population who will be using the CAI, possibly even allowing them to participate in deciding the objectives.

It would also be important to the Gestalt theorists that the behavior expected of the students using the program would be purposeful (meaningful) to the student. This would suggest close observation to determine the "areas" which are likely to interest the students at the age the CAI is planned to be used. Since the Gestalt theorists would say we make a response because we expect a specific outcome, it woul be important to relate the objectives in such a way as tobe meaningful in outcome to the student. This might suggest our curriculum should be utilitarian in nature.

Also related to this phase of development would be Bandura's suggestion concerning attention to learning. As we develop the objectives we should probably state them with the idea they can be taught in such a way as to involve the student in the learning.

Gestalt theorists would suggest the CAI be developed in such a way as to allow the use of the discovery method of learning for the student. The use of a computer for problem solving would probably put a smile on these theorists faces. Perhaps organizing the material into unified sections which the student can choose to do in the order and time they desire would be appropiate.

Once the objectives have been determined it becomes important to develop the content of the CAI. This involves both the specific content of the CAI and the method of presentation.

A. What do I want to teach, and the students want to learn?
   1. Is the material presented in such a way to allow students to comprehend it?
   2. Is the objective meaningful to the students?
   3. Can I involve the student activly in accomplishing these objective?

Content Development

Cognitive theory has much to say concerning the development of this phase of CAI. Of importance is the overall presentation of the material. As suggested by the Gestalts all the content should be organized in such a way as to seem continuous and united. Rather than being organized from the simple to the complex, content should be organized in simplified wholes which lead to more complex wholes.

Piaget would suggest activities which provoke thought about change and the relative nature concerning a fact, rather than discrete or absolute facts themselves.

Once the content has been developed it should be categorized into simlified units for frame design.

B. Does the content suggest unity?
   1. Is the sequence from simplified wholes which lead to complex wholes?
   2. Does the content suggest processes or facts?

Frame Design

The layout of the screen would be very important to the Gestalts. When designing the frames the principle of closure should be kept in mind, i.e., all the information presented on each screen should appear to be united. It should exemplify unity. Based on this principle, closed areas are more readily seen as units. Therefor a screen which is bordered, or on which the information has been displayed in a unifying manner will increase the student's retention and understanding of the material presented.

The frame design should also allow the student to control the advancement to the next frame, as well as selecting the sequence, as stated earlier. Various functional areas of the screen, such as information display, instructional area or error messages, should be kept in the same area throughout the CAI. This incorporates the Gestalt principle of similarity.

Piaget, Estes, and Bandura would suggest thought provoking action, or motor activity be designed within the frame to encourage the student to "attend to learning." Asking students to respond to various questions or to control the advancement of the next frame are techniques which may be used to accomplish attention to learning.

The use of memory and information processing techniques, such as relating graphics to content to encourage retention would also be important in this phase of CAI design. Some of the techniques Bandura suggest for retention, such as coding, motivation, and rehersal are appropriate and readdily possible on a computer.

Once the frames for instruction have been completed a method of feedback must be designed. This will provide for improvement of later instruction and allow the computer to customize to the various students.

C. Do the various frames suggest continuity and unity in appearance and content?

1. Are the frames closed in appearance?
2. Can the student conrol the display of various frames?
3. Is motor activity used to encourage active learning?
4. Have memory processing techniques been incorporated in the design?

Feedback Design

Important in the design of feedback would be the Mathematical Learning Theory. Though this theory deals basically with methods of research, it also may be applied in CAI development. For example, when designing feedback it would be very useful to save information concerning response time, incorrect responses, etc. on each individual student. The information could then be used by the computer to design a custom program, based on "computer observations," which have been analyzed using the Mathematical Learning Theory as a model for development. In this way the more a student used a CAI program the better a computer or teacher would know about the student, and the more customized and effective the instruction could be (The problem CAI designers are facing now is how to store all the data. Once they have this solved you will probably see CAI programs which incorporate this technique. Some CAI already incorporates simple evaluative techniques.)

Motivators would be important for feedback and the result of correct behavior must be the expected outcome the student is expecting. Again, possibly presenting information the student hasn't learned in another way following an incorrect response might assist the student in unifying the various concepts beeing taught.

A CAI which does not provide opportunity for post assessment probably will never be developed to an effective level, since it is very seldom a CAI comes out of the factory in perfect form. Therefor it is necessary to develop post assessment.

D. Have student expectations been considered in the feedback design?

1. Are meaningful motivators present?
2. Is immediate feedback provided the student?

Post Assessment

Post assessment could be modeled very close to the suggestion made in feedback design. The difference would be the computer would analyze the data of all the students collectively and come up with suggestions based on the analysis. Again the Mathematical Theory of Learning could be used as a model fo developing and interpreting the data in postassessment.

Postassessment also involves evaluating the student to determine whether he has accomplished the objectives. The program should leave the student in closure, i.e., the student should be aware of his progress and the level of accomplishment. Gestaltist would also say it would be important to inform the students of the objectives they had not accomplished.

E. Has provision be made for post assessment?

1. Has the student's progress been analysized?
2. Has closure been provided the student?

Summary

Learning theory can provide a sound foundation from which to design instruction. However, to be effective it is necessary for the instructional designer to be aware of the discussions, recent findings, and explanations of the various learning theorists.

It is also important to be open minded and seriously consider altering or changing your instructional methods as new light is shed on the process of learning. When I began this paper I was under the impression I conformed to the

modern techniques and findings of learning theorists. However as I gathered the material and information for this paper I found myself wondering where I had been for so long.

From Thorndike to Skinner, to Piaget to Rotter, all have much to offer, whether it be only cause for a critical evaluation of beleifs concerning learning, or the suggestion of a new paridqm for the next generation. One thing is certain, more discoveries will be made and more theories written. Theories of the past will merge into new theories for the future. And learing will be better because of it.

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